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Soil Compaction: Are Things Changing?

In Situ Measurements of Subsoil Settlement under Heavy Wheel Loads

At the Institute for Production Engineering and Building Research of the German Federal Agricultural Research Centre in Braunschweig, a measurement system has been developed which enables in situ vertical soil displacement measurements in the subsoil, caused by travelling with heavy wheel loads. In contrast to others, this method [1, 2] makes it possible to drastically reduce the input required for field measurements by using further-developed technology. The simple handling permits simultaneous measurements at different soil depths with multiple parallel measurements each time. In field trials, promising and reproducible results were obtained for different soils, under different soil conditions and loads.

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In the surface, the deformation of the soil under wheel loads is visible through the creation of wheel tracks. The basic idea for in situ measurements of soil displacement at various depths emerged from efforts to follow the further course of vertical soil movements from the surface into deeper soil [3, 4]. One possibility is the measurement of vertical (and, if necessary, horizontal) movements of plates or other testing implements placed in the soil and connected to electromechanical position sensors. Due to the great effort required to equip such a measurement site in the subsoil (destruction of soil), and the sensitivity of mechanical components to disturbances, a more practicable measurement method had to be looked for.

The principle of a water level gauge

The water level gauge (*Fig. 1a*) has already been utilised for periodical measurements of vertical soil deformation to examine bulk density dynamics of soil profiles [5]. However, it is especially used in construction technology [6, 7] as a simple but precise aid to locate identical levels at two sites between which no optical contact is possible. According to the principle of communicating pipes, both sides of a U-formed hose filled in part with water result in identical water levels (provided that the same atmospheric air pressure $p_{atm.}$ affects both hose ends). By sealing one end of the hose with a pressure transducer, the level gauge becomes a hydrostatic level measurement system. With a differential pressure transducer (*Fig. 1b*) the influence of atmospheric pressure variations is compensated. This modern variant of the water level gauge is used in construction measurement technology, e.g. to monitor settlement in buildings or landfill areas. A further improvement is the self contained system in *Fig. 1c*, which avoids errors, induced by differences in atmospheric pressure between the two ends of the level gauge.

The hose in hose system

The own further development aimed at inserting the free hose end through a slanted hole down to the desired measurement position in the soil, establishing equal atmospheric pressure at both the hose end and the pressure transducer and thus preventing the hanging water column from tearing. The "hose in hose" system was developed as the solution to these problems, as sketched in *Fig. 1d*, in which the open, water-filled hose is located in an enveloping hose with a closed end. The result is a self contained, air pressure independent system from which no water can escape. A polyamide hose with 4 mm interior diameter which adjusts well to the movements of the surrounding soil is used as the enveloping hose. The inner water hose has an inner diameter of 1 mm with a wall thickness of 1 mm as well. Through the capillary effect of the small hose diameter, the water column is additionally stabilized. Changes in the air pressure as a consequence of deformation or temperature changes within the enveloping hose are compensated by the differential measurement within the closed system. In order to prevent air bubbles, which would lead to errors in the transfer of pressure, the system is preferentially filled with degassed water.

To fill the hose probes and to connect with the pressure transducer, a special armature was developed for easy operation in the field. The miniature differential pressure transducers are integrated in the armature and thus well-protected mechanically. The measurement range of the pressure transducers used is 100 mbar or rather 100 cm water column. The pressure signals are amplified over highly stable instrumentation amplifiers that - with the subsequently switched data acquisition system, comprised of a notebook and a USB analogue-to-digital converter box - a useable measurement range window of 400 mm is achieved at a resolution of 0.1 mm.

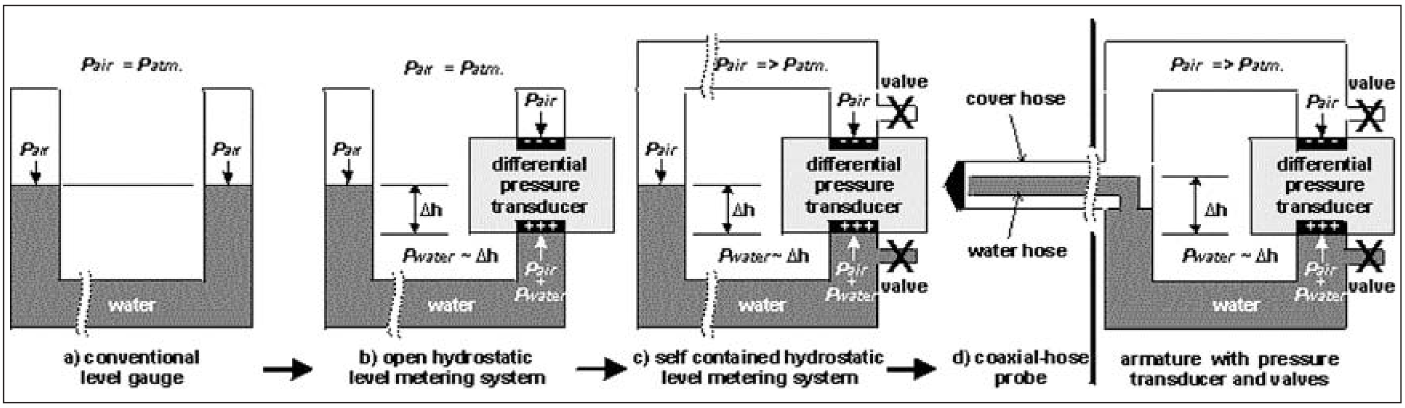

Fig. 1: Development steps of the hydrostatic level metering system

Results of a field test

The following example is taken from a test series, in which the influence of the tire inflation pressure on the pressure distribution in the soil and on the attending settlement in the respective depths was studied.

The testing areas on a conservationally tilled soil were rolled over several times with the rear axle of a charged tractor. The wheel load was 4.1 tons. The soil pressure was measured with hose probes (acc. to Bolling), which, together with the settlement probes were installed at a depth of 40 cm under the middle of the travelling lane.

Figures 2a and 2b show the measurement results for both inner tire pressures 0.8 bar and 2.1 bar. Despite the comparably large change in inner tire pressure, the soil pressure values measured at a depth of 40 cm are almost identical at about 0.4 bar. In the settlement a significant difference can be seen between the two variations. While at 0.8 bar inner tire pressure, only an elastic deformation takes place at the moment of rolling over, at the high inner tire pressure a plastic portion remains, which sums up to a total settlement of about 2 mm after four passages. It is noteworthy that in both variations the elastic portion of the settlement is in each case constant at about 3.5 mm.

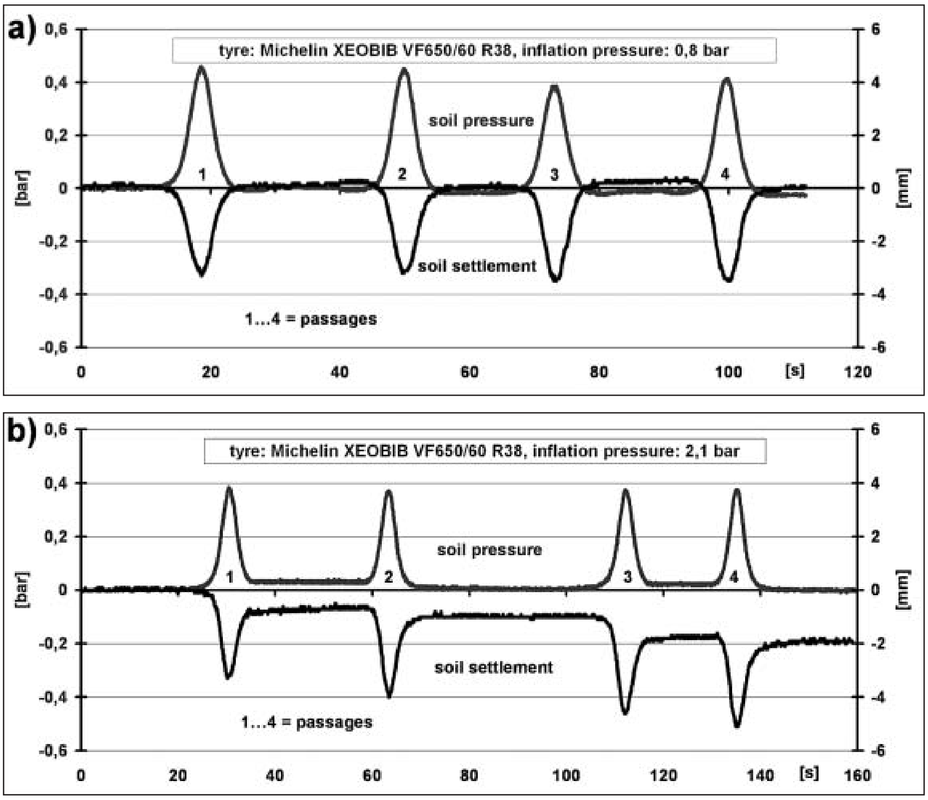

Fig. 2: Soil pressure and settlement with 4.1 t wheel load and a) 0.8 and b) 2.1 bar tire inflation pressure

Conclusion and prospects

Particularly in the case of systematic field studies on the problem of soil compaction, the method shows its advantages: its simplicity permits the acquisition of settlement data in soil profiles with only minimal disturbances of the soil structure and even without taking soil samples to an extent, which was not yet possible due to the large difficulties of establishing measurement sites.

With regard to the project goal - development of a trafficability-sensor - the described measuring method can provide an important contribution: to interrelate the settlement at the surface (depth of wheel ruts) to the settlement (soil deformation) down to the subsoil.

For soil protection in terms of avoiding deterioration of the natural soil functions even in the subsoil a way to an alternative approach for the development of a trafficability-sensor becomes apparent: „Are things moving ?“ – thus, down to which depth „may“ something move when arable soil is passed over with heavy loads.

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